Second, the USADR receiver will perform its DAB processing in a digital signal processing chipset. The chipset decodes analog AM and FM and DAB AM and FM in both the hybrid and all-digital modes. This chipset replaces a single-chip AM/FM demodulator that is common in many radios.

Affordable receiver implementation is also realized through integration of the AM and FM receive paths, which allows maximum duplication of receiver circuitry for both the AM and FM modes. In fact, since most of the receiver functions can be performed in the digital signal processing chipset, AM IBOC radio can be integrated with FM IBOC radio with virtually no additional circuitry (other than that required by the receiver front end).

**MLJ** *MOFFET, LARSON & JOHNSON, INC.*
*CONSULTING TELECOMMUNICATIONS ENGINEERS*

1110 N. Glebe Road, Suite 800 Arlington, VA 22201

ENGINEERING REPORT

# EXISTING FM INTERFERENCE STUDY

October 5, 1998

# TABLE OF CONTENTS

# Executive Summary

This report presents the results of studies to characterize present interference in the FM band. The USADR DAB system enables an FM station to transmit digital signals on its own channel, and is thus characterized as in-band, on-channel (IBOC).

Two types of interference studies were conducted. Initial distance separation studies were performed to generally characterize the extent of various types of interference, such as first adjacent channel and cochannel interference. Secondly, interference calculations were completed to determine predicted coverage and interference areas for each station in the conterminous United States. The report includes maps showing predicted coverage and interference for worst case, best case, and typical stations. The stations for the worst cases were selected to show various types of predicted interference.

In addition, predicted coverage and interference maps for every station on four representative interference channels are shown. Because of the manner of the development of the FM broadcasting service, FM interference within areas normally protected from interference may be more widespread than would be intuitively expected. Some stations receive little or no interference, even beyond normally protected contours, and other stations are severely impacted. The studies show that interference is most pronounced from the northeast to Chicago, and also on the west coast near Los Angeles and San Francisco. It is evident from the FM studies conducted on behalf of USADR that interference generally limits both analog and digital service. Any DAB system must take interference constraints into account in order to operate successfully.

# Existing FM Interference Study

## Engineering Statement

### Introduction

Moffett, Larson and Johnson, Inc. (MLJ) has been retained by USA Digital Radio, L.P. (USADR) to conduct engineering studies in support of the USADR petition for rule making to permit digital radio operation in the aural broadcasting bands. USADR is developing digital aural broadcasting (DAB) systems to operate in both the AM and FM broadcasting bands. The MLJ studies in this exhibit relate only to the FM DAB. The USADR system enables stations to transmit digital signals on the same channel used for analog operation. The DAB signals are within the emission specifications or "mask" of the Commission's rules. The systems are thus characterized as in-band, on-channel (IBOC). The purpose of this report is to characterize the existing FM interference environment.

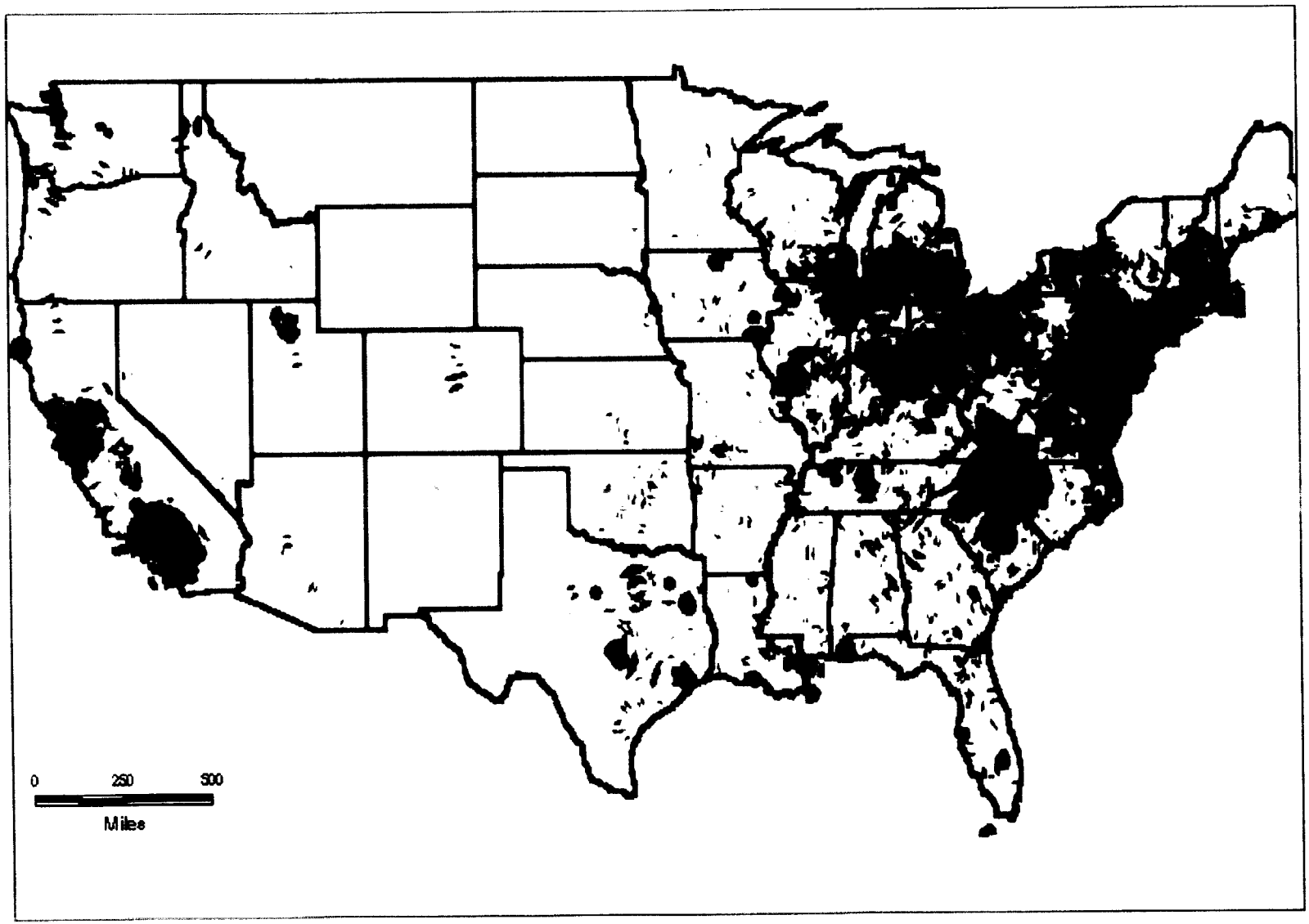
### Scope of the Studies

Two types of interference studies were conducted to characterize existing analog FM interference. Initial distance separation studies were done on commercial channels to characterize generally the extent and sources of analog interference. This study was used to identify worst cases of interference by several important criteria, such as the severity of short spacing and the presence of multiple interferers. The data developed in this phase of the study could also be used as an aid in the design of the USADR system. A second set of interference studies were performed by Dataworld to compute predicted coverage and interference areas for each station in the conterminous United States.

### Distance Separation Studies

As a first step in assessing analog interference, distance separation studies were performed on all commercial stations within the conterminous United States. Our study identified more than 2600 pairs of short-spaced commercial stations, and more than 4800 pairs of stations either short spaced or within 5 kilometers of the minimum separation. Of the approximately 5600

# Overlapping Coverage and Interference Contours




MLJ

FIGURE 1

commercial FM stations, 3280 (approximately 60 %) have at least one short spacing. For each pair of closely spaced or short-spaced stations, coverage and interference contours were drawn based on each station's reference facilities.[1] Figure 1 is a map showing areas where protected and interfering contours overlap. As expected, this map shows that interference is pronounced from the northeast to Chicago, and also on the west coast near Los Angeles and San Francisco. The areas shown are contour overlap areas; predicted interference areas would generally be smaller. Even so, Figure 1 shows that interference is extensive and that interference considerations are of paramount importance in IBOC DAB system design. Many of the areas shown in Figure 1 may receive interference from multiple sources. An FM IBOC system should be designed to be as robust as possible to operate in the crowded FM analog environment.

The distance separation studies were based on Section 73.207 of the FCC's rules, including cochannel, first adjacent, and second adjacent channel stations. Because of the design of the USADR IBOC system, digital reception is essentially not susceptible to third adjacent channel interference; nor is IBOC likely to increase the potential for causing such interference to analog stations. Thus, third adjacent channel interference was not studied. The studies are confined to the non-reserved band or "commercial band", that is, channels from 221-300 inclusive. Stations in the band reserved for non-commercial, educational (NCE) operation have been assigned on a protected-contour basis so that separation studies would be largely irrelevant. There are approximately 1870 cases of second adjacent channel short spacings. Of these, in about 270 cases the interfering station is within the desired station's protected contour.

[1] Licensed effective radiated power and antenna height above average terrain were used along with FCC F(50,50) and F(50,10) contours to compute distances to contours. Directional antenna patterns and antenna HAAT on specific radials were not considered at this phase.

The separation studies identified several other criteria which may affect the operation of an FM DAB system. For example, we identified nearly 700 areas in which interference may be received from at least two separate sources. Based on these studies, three examples of worst case, average or typical case, and best case stations were selected as candidates for more detailed interference studies.

## Detailed Interference Studies

The results of the detailed interference studies are shown in Figures 6 through 14, which are maps showing the selected station's predicted protected contour and predicted interference within that contour. A discussion of each figure and a summary table presenting area and population data is presented on a page after the interference maps.

Interference maps for the three "worst case" stations are shown in Figures 6 through 8. Additional "worst case" maps are shown in Supplement A. The methodology of the distance separation studies used for station selection and discussion of the studies are included in Supplement B.

Interference maps for "average" stations are shown in Figures 9 through 11. As is described later in this report, FM service normally extends beyond the protected contour and is ultimately limited by noise. The 44 dBu contour is used here as the noise-limited contour; the derivation of this value is discussed in Supplement C. Figures 9 through 11 show the stations' predicted 44 dBu contour in addition to the stations' normally protected contour. The stations were selected by sorting results of the overall interference studies and selecting stations for which percentages of potential interference approximated the median, both in area and population. To provide balance, a small and a large market commercial station were chosen. The stations are WWRZ, Arcadia, Florida and WPOC, Baltimore, Maryland. In addition, a noncommercial FM station is included. The coverage of WFRZ, Columbus, Georgia approximates the median of the reserved band stations with respect to magnitude of the coverage area as well as in percentages of predicted interference.

Interference maps for "best case" stations are shown in Figures 12 through 14. There are numerous stations with no predicted interference within the normally protected contour and some stations with interference-free service out to the noise-limited contour. Figures 12 through 14 show the stations predicted 44 dBu contour as well as the nominal 60 dBu service contour. Stations whose coverage is limited by noise only tend to be found in the western mountain states such as Utah and Nevada.. For example, service of stations such as KCSP, Casper, Wyoming and KKAT in Ogden, Utah are limited by noise, not interference. To provide geographic diversity, best cases for detailed study were selected in major markets on the west coast, near the center of the country and on the east coast. Stations in very rough terrain were avoided. Thus the selected stations are expected realistically to serve large areas and populations. The selected stations are KPDQ, Portland, Oregon; KSLZ, Saint Louis Missouri,

and WAFX Suffolk, Virginia, which is in the Norfolk market. There is no predicted interference within the protected contour of these stations and only minor interference within the noise-limited contour. In the case of KPDQ, there is no interference within the station's present predicted noise limited contour, however there is an outstanding construction permit for a new station at Tillamook, Oregon that would ultimately cause interference.

The following D/U ratios are used to define the threshold of interference:

| | |
|---|---|
| Cochannel | 20 dB |
| First Adjacent Channel | 6 dB |
| Second adjacent Channel | - 20 dB |

The value of - 40 dB has been used for second adjacent channel interference as well as third adjacent channel interference. The - 20 dB value has been used for second adjacent channel in the NCE rules to date although in MM Docket No. 98-93 the Commission has proposed to adopt the -40 dB value for NCE allocations. In this case the more conservative value is used because a primary concern is not to risk understating interference on a large scale.

**Figures 2 through 4**
**Examples of "Worst-case" Interference**

# PREDICTED ANALOG INTERFERENCE TO WIST-FM CH 252A THOMASVILLE, NC

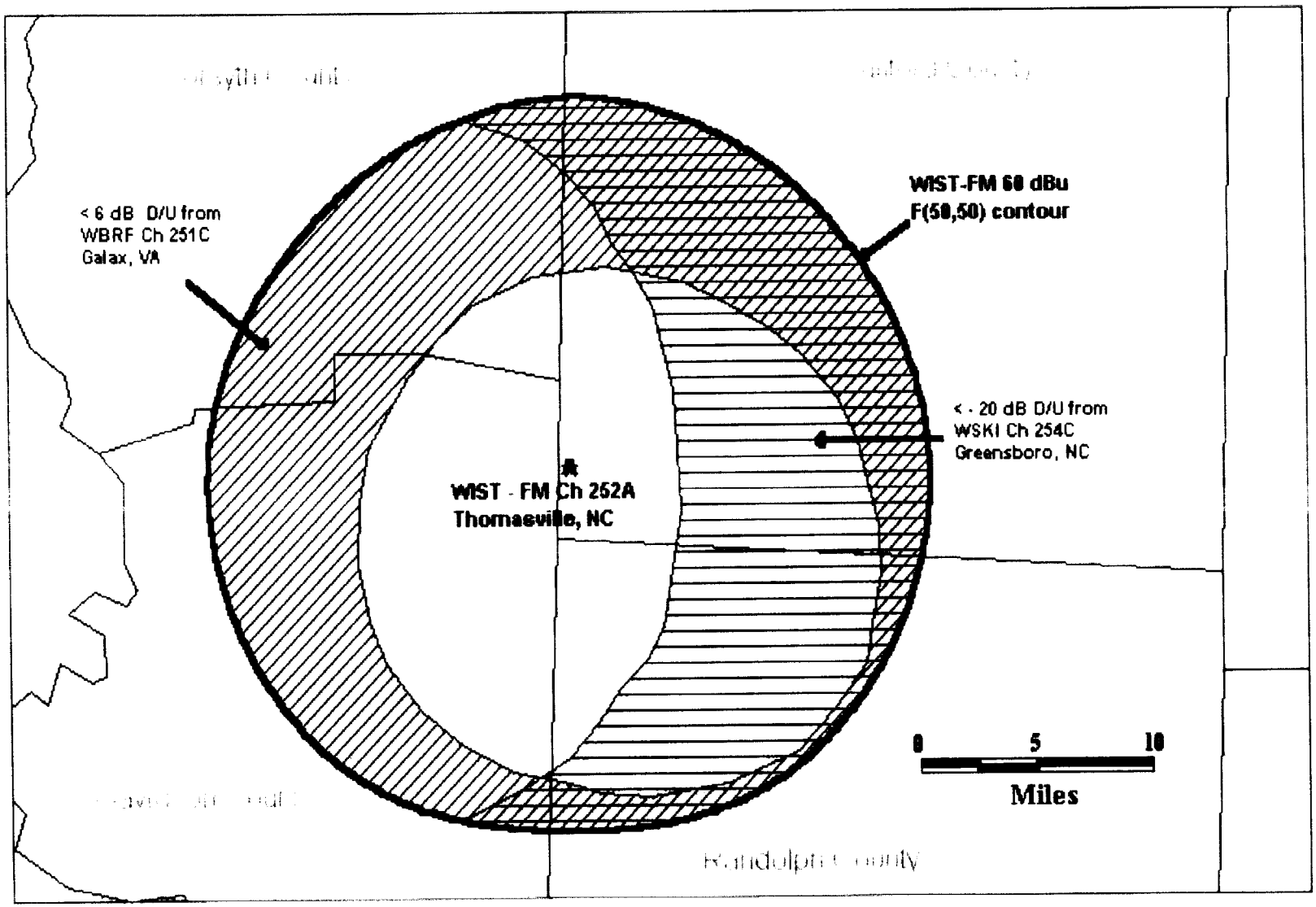



**FIGURE 2**

**MLJ**

**PREDICTED ANALOG INTERFERENCE TO WIST-FM CH 252A THOMASVILLE, NC**

**Within WIST - FM 60 dBu: 389,259 persons in 698 sq. mi.**

| Interference from Station: | Affected area sq. mi: | % of Total: | Affected Population: | % of Total: |
|---|---|---|---|---|
| WBRF | 334 | 47.9 | 154,787 | 39.8 |
| WKSI | 288 | 41.3 | 92,900 | 23.9 |

Station WIST, a Class A station, is severely short spaced to two class C stations: WBRF on the lower first adjacent channel and WKSI on the upper second adjacent channel. WIST is 68.0 kilometers short of the minimum distance to WBRF, and 75.8 kilometers short to WKSI. As a result the predicted WIST-FM interference-free area is substantially reduced from the normally protected coverage area. The interference-free area contains 125,376 persons in 208 square miles. These values represent losses of approximately 70 percent, that is, loss in area of 70.2 percent and 67.8 percent of population.

# PREDICTED ANALOG INTERFERENCE TO KBUA - CH 232A SAN FERNANDO, CA

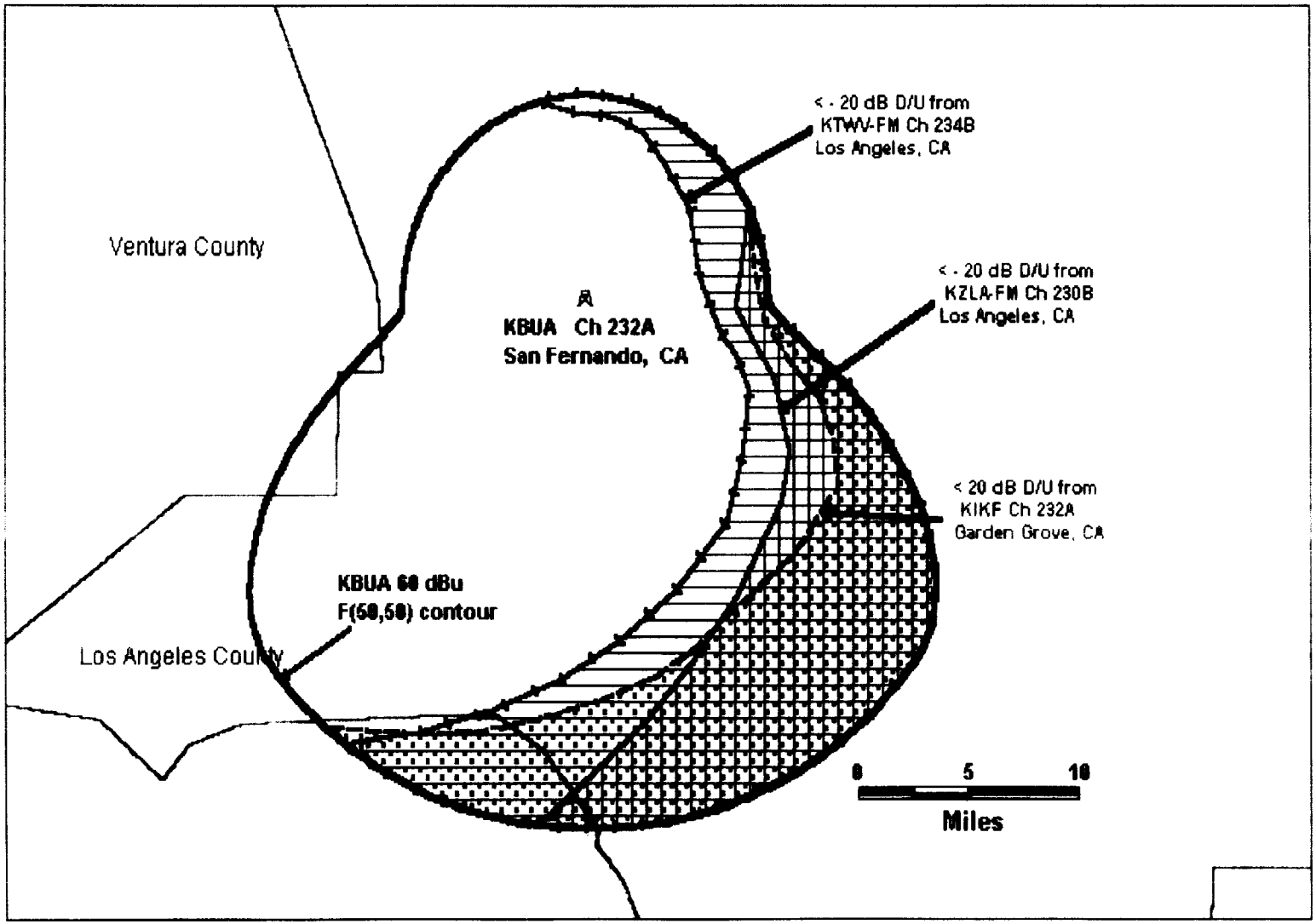



**FIGURE 3**

MLJ

**PREDICTED ANALOG INTERFERENCE TO KBUA CH 232A SAN FERNANDO, CA**

**Within KBUA 60 dBu: 3,182,326 persons in 612 sq. mi.**

| Interference from Station: | Affected area sq. mi: | % of Total: | Affected Population: | % of Total: |
|---|---|---|---|---|
| KTWV | 222 | 36 3 | 1,890,701 | 59.4 |
| KZLA | 148 | 24 2 | 1,531,638 | 48.1 |
| KIKF | 139 | 22 7 | 1,616,912 | 50.8 |

Station KBUA receives substantial interference because it is short spaced to two "super" Class B stations on Mount Wilson at Los Angeles. Station KTWV-FM operates with 52 kW ERP and a nominal antenna HAAT of 863 meters, whereas normal maxima for a Class B station are 50 kW and 150 meters. The actual KTWV-FM effective antenna height towards the interference area is approximately 1400 meters. Because the area of predicted interference falls in the Los Angeles metro area, KBUA loses approximately 60 percent of the population within its normally protected 60 dBu contour.

PREDICTED ANALOG INTERFERENCE TO WJFK-FM CH 294B MANASSAS, VA

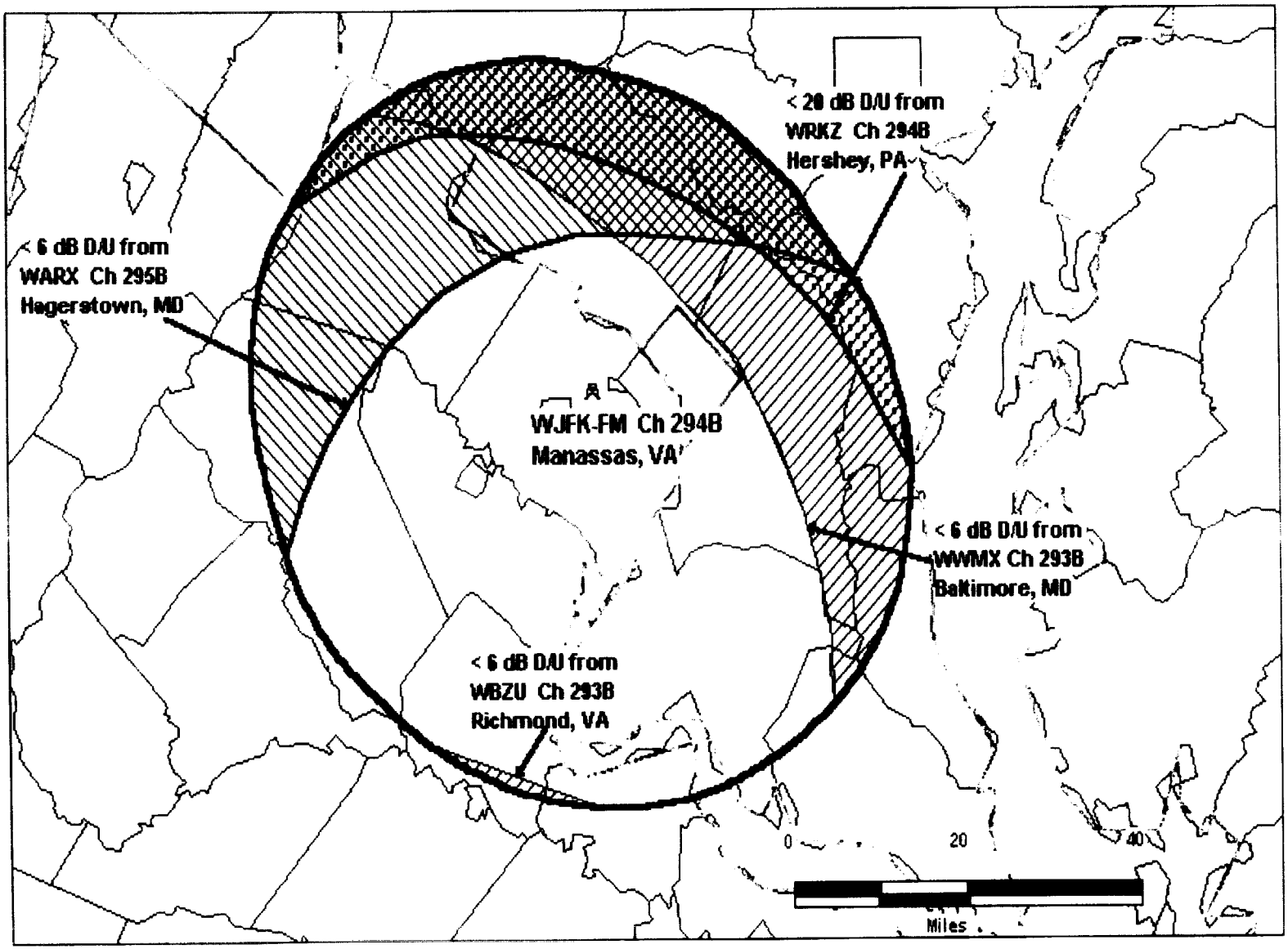



FIGURE 4

MLJ

**PREDICTED ANALOG INTERFERENCE TO WJFK-FM CH 294B MANASSAS, VA**

**Within WJFK-FM 54dBu 3,917,255 persons in 4224 sq. mi.**

| Interference from Station: | Affected area sq. mi: | % of Total: | Affected population: | % of Total: |
|---|---|---|---|---|
| WARX | 1169 | 27.7 | 490,519 | 12.5 |
| WMMX | 1075 | 25.4 | 1,120,510 | 28.6 |
| WRKZ | 526.5 | 12.5 | 252,615 | 6.4 |
| WBZU | 18.37 | 0.4 | 8,498 | 0.2 |

WJFK-FM receives extensive interference from stations WARX and WMMX on the upper and lower first adjacent channels. A large and populous area (401,297 persons in 519 square miles) is predicted to receive interference from both upper and lower first adjacent channels simultaneously. This area represents 10.2 percent of the population and 12.3 percent of the area within WJFK-FM's 54 dBu service contour

The WJFK-FM net interference-free area contains 2,761,590 persons in 2453 square miles. Thus, the loss area is 1771 square miles or 41.9 percent of the predicted WJFK-FM normally protected coverage area. The population within the predicted loss area is 1,155,665 persons or 29.5 percent of the predicted WJFK-FM normally protected coverage area.

**Figures 5 through 7**

**Examples of "Typical" Interference**

PREDICTED ANALOG INTERFERENCE TO WPOC CH 226B BALTIMORE, MD

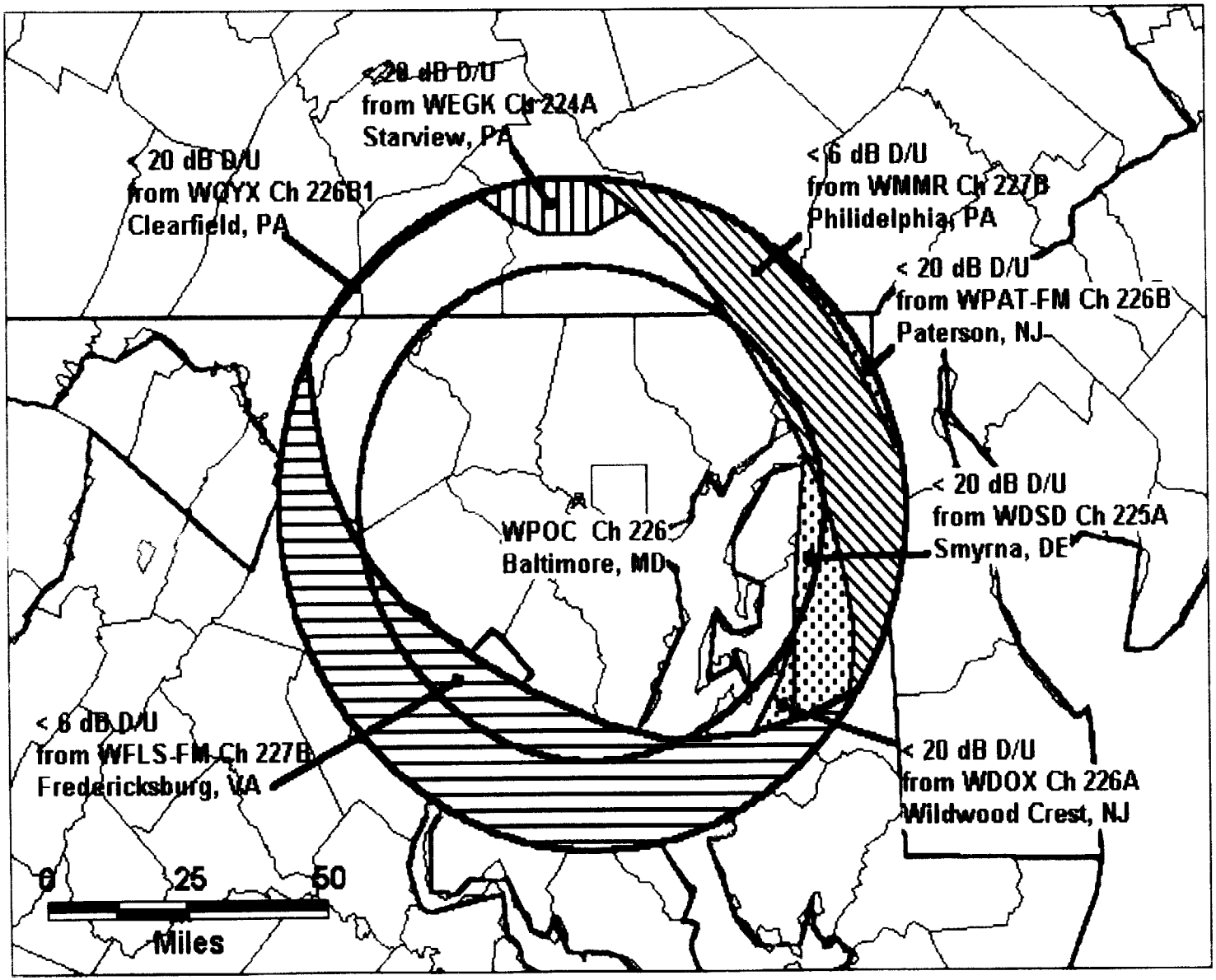



FIGURE 5

MLJ

## PREDICTED ANALOG INTERFERENCE TO WPOC CH 226B BALTIMORE, MD

**Within WPOC 54 dBu: 5,235,480 persons in 4,548 sq. mi.**

| Interference from Station: | Affected area sq. mi: | % of 54 dBu area: | Affected population: | % of 54 dBu total: |
|---|---|---|---|---|
| WFLS | 421 | 9.3 | 956,605 | 18.3 |
| WDSD | 89 | 2.0 | 4,220 | 0.1 |
| WMMR | 48 | 1.1 | 10,220 | 0.2 |

**Within WPOC 44 dBu: 6,644,150 persons in 8,541 sq. mi.**

| Interference from Station: | Affected area sq. mi: | % of 44 dBu area: | Affected population: | % of 44 dBu total: |
|---|---|---|---|---|
| WFLS | 2,148 | 25.1 | 1,857,665 | 28.0 |
| WDOX | 1,143 | 13.4 | 111,460 | 1.7 |
| WMMR | 1,128 | 13.2 | 157,185 | 2.4 |
| WDSD | 993 | 11.6 | 90,465 | 1.4 |
| WEGK | 197 | 2.3 | 148,405 | 2.2 |
| WPAT | 65 | 0.8 | 19,640 | 0.3 |

# PREDICTED ANALOG INTERFERENCE TO WWRZ CH 252A ARCADIA, FL

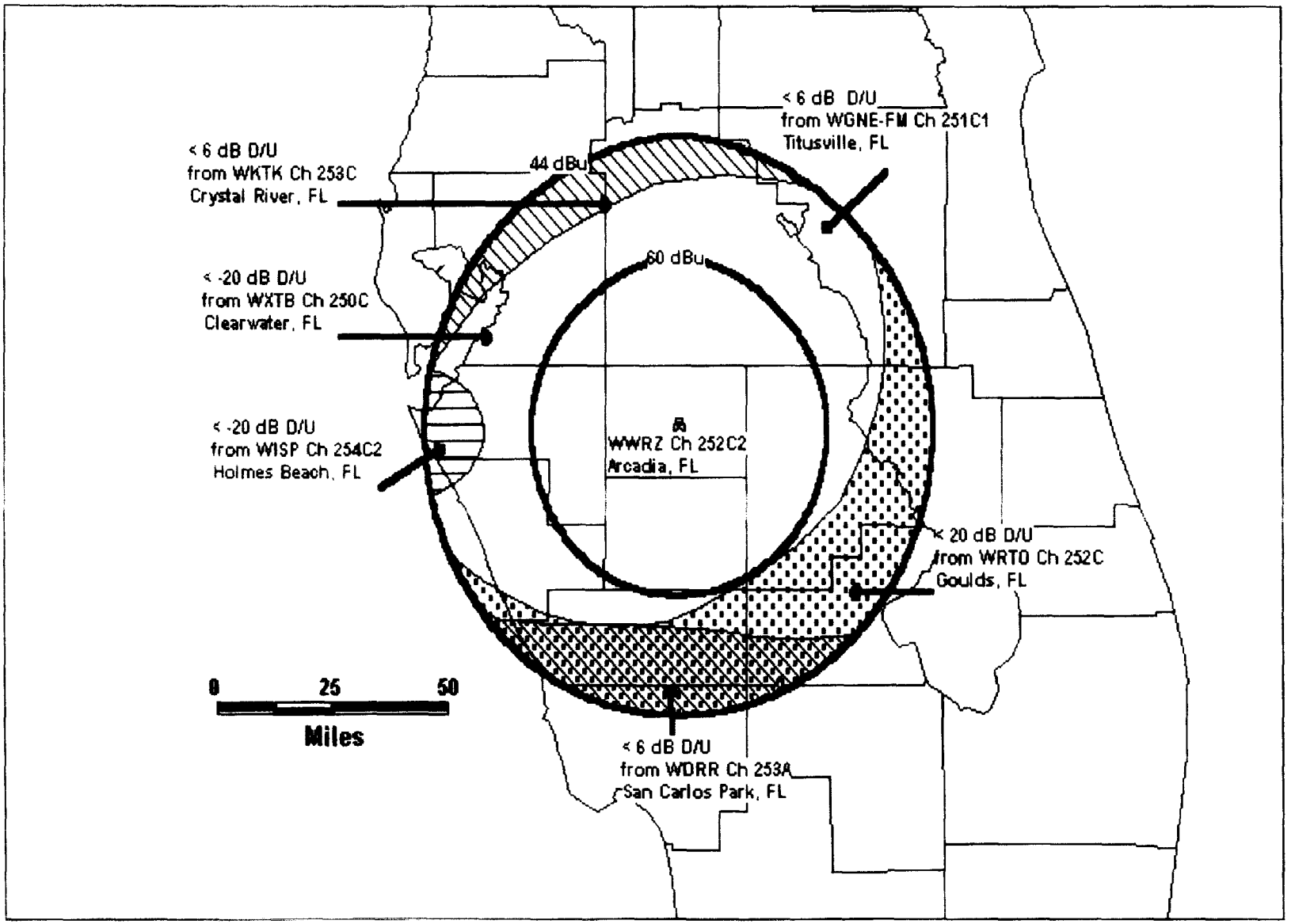



**FIGURE 6**

**MLJ**

## PREDICTED ANALOG INTERFERENCE TO WWRZ CH 252C2 ARCADIA, FL

**Within WWRZ 44 dBu: 1,631,140 persons in 8,864 sq. mi. (land area)**
**Within WWRZ 60 dBu: 159,400 persons in 3,123 sq. mi.**
**Net interference-free service area: 968,030 persons in 5,484 sq. mi.**

| Interference from Station: | Affected area sq. mi: | % of 44 dBu area: | Affected population: | % of 44 dBu total: |
|---|---|---|---|---|
| WDRR | 846 | 9.5 | 78,155 | 4.8 |
| WGNE | 1,069 | 12.1 | 64,325 | 3.9 |
| WISP | 173 | 2.0 | 200,835 | 12.3 |
| WKTK | 641 | 7.2 | 326,370 | 20.0 |
| WRTO | 2,176 | 24.5 | 102,055 | 6.3 |

**There is no predicted interference within WWRZ's 60 dBu service contour.**

# PREDICTED ANALOG INTERFERENCE TO WFRC CH 213C3 COLUMBUS, GA

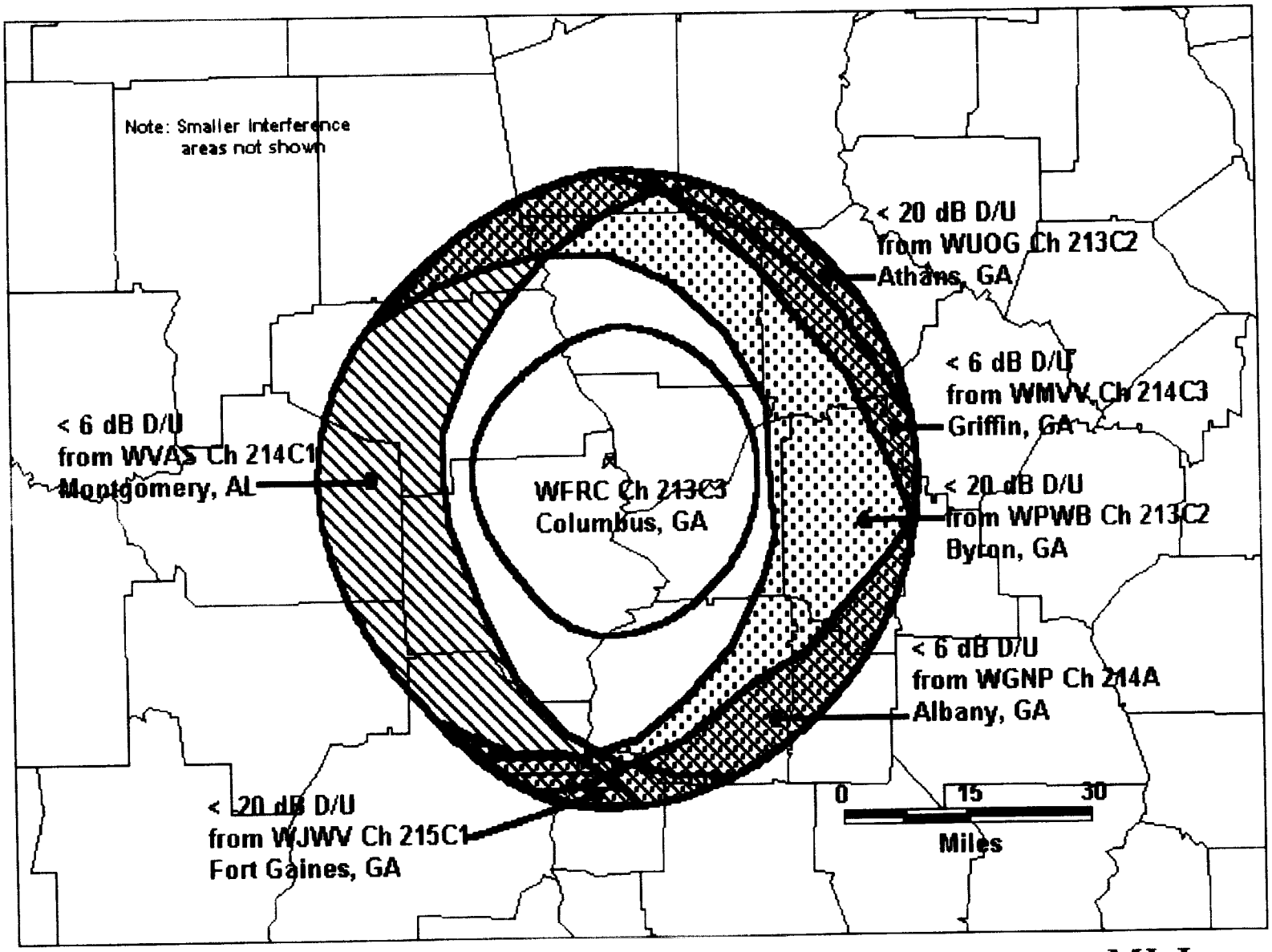



**FIGURE 7**

MLJ